TOLERANCE OF WINTER CANOLA (*Brassica napus*) CULTIVARS TO SELECTED RESIDUAL HERBICIDES

By

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TOLERANCE OF WINTER CANOLA (*Brassica napus*)

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HERBICIDES

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TOLERANCE OF WINTER CANOLA (*Brassica napus*) CULTIVARS TO SELECTED RESIDUAL HERBICIDES

TOLERANCE OF WINTER CANOLA (*Brassica napus*) CULTIVARS TO SELECTED RESIDUAL HERBICIDES

B. HEATH SANDERS[1]

Winter canola planting continues to increase in Oklahoma and the Southern Great Plains due to the need for a winter broadleaf crop to rotate with winter wheat in order to expand weed control options. ALS-inhibiting herbicides are commonly used in winter wheat each year in this region. Several of these herbicides have rotational crop restrictions that do not permit seeding winter canola the following year. Field experiments were conducted from 2005 to 2007 and repeated from 2006 to 2008 at three sites to evaluate canola tolerance to ten selected ALS-enzyme inhibiting herbicides. Factors included herbicide treatment applied to wheat and canola cultivar seeded the following fall. The two canola cultivars seeded vary in response to ALS herbicides. The ten herbicides, all registered for use in wheat, were applied at 1x and 2x rates. Additional experiments were conducted to investigate the response of the same two canola cultivars to multiple rates (one-half to five times the labeled rate) of chlorsulfuron + metsulfuron. Application of ALS-inhibiting herbicides to wheat seeded in December caused visible

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stunting and chlorosis to canola seeded the following fall at two sites one year and no sites the other year. However canola yield was not reduced by any herbicide treatment applied to any experiment either year. The data suggest that winter canola can be grown with a much shorter rotational interval than recommended on some product labels.

Nomenclature: chlorsulfuron; chlorosulfuron + flucarbazone,; chlorsulfuron + metsulfuron; mesosulfuron; metsulfuron; propoxycarbazone; propoxycarbazone + mesosulfuron; sulfosulfuron; thifensulfuron +tribenuron; triasulfuron; canola, Brassica napus L. 'DKW 13-86' and 'Sumner'; wheat , Triticum aestivum L.

Keywords: ALS-inhibiting, crop rotation, winter wheat.

INTRODUCTION

Winter canola has been increasing in Oklahoma in response to the need for a winter broadleaf crop rotation with winter wheat. Crop rotations help manage weeds that have become adapted to a certain cropping systems (Monaco, 1991). The lack of crop rotation for winter wheat has led to increasing problems with winter annual grass weeds and increased dependency on herbicides for their control. Weeds generally thrive in cropping systems that are similar to the growth and characteristics of their own (Liebman and Dyck, 1993). The use of different crops changes the cultural conditions and necessitates often results in different herbicides being used (Monaco, 1991). Wheat growers are increasingly recognizing the need for a winter rotation crop that will fit into their winter wheat cropping system. Winter crops tend to have a higher success rate if weather conditions are normal in Oklahoma (Peeper et al., 2008). As new adapted varieties of winter canola have been developed, winter canola has become a more appealing winter cropping option for wheat farmers in Oklahoma and the Southern Great Plains.

Winter wheat is a flexible crop in the Southern Great Plains where it is used for forage, forage and grain, or grain alone (Krenzer, 1994). Oklahoma producers spread their financial risk by utilizing the winter wheat forage available in the fall and winter months then harvesting the grain in the late spring. They can adjust their emphasis towards forage or grain production depending on environmental conditions and markets. These traditional farming practices have led Oklahoma producers to rely heavily on a continuous monoculture cropping system. Winter canola offers producers a winter annual broadleaf crop that will assist in breaking weed and disease cycles that plague continuous winter wheat fields.

One of the most important factors to consider prior to planting winter canola is field site selection including past weed and herbicide use histories (Anonymous 1996, 2007b, 2009b; and Hang et al. 2009). Herbicide carryover is a problem when herbicide residues limit a producers crop selection options (Brewster and Appleby, 1983).

Acetolactate synthase (ALS)-inhibiting sulfonylurea herbicides are used for broad spectrum weed control at low use rates, with good crop selectivity and low acute and chronic activity (Brown, 1990). The mode of action for these herbicides inhibits branch chain amino acid production by the inhibition of the enzyme acetolactate synthase ALS (Anonymous, 2007b). These herbicides are potent inhibitors of growth, with root and shoot growth severely inhibited in sensitive seedlings (Beyer, 1988). Visual symptoms of phytotoxity include vein reddening, leaf chlorosis, terminal bud death, and necrosis slowly developing a few days after treatment (Brown, 1990).

ALS-inhibiting herbicides generally persist in the soil for a given amount of time depending on environmental conditions. Degradation of these herbicides in the soil is from chemical hydrolysis or microbial breakdown. Major factors that have the greatest impact on chemical hydrolysis and microbial breakdown are temperature, pH, soil moisture, and soil organic matter (Beyer, 1988). Since some sulfonylureas are weak acids, hydrolysis takes place much faster under acidic conditions in the soil, thus hydrolysis is pH dependent (Hay, 1990). The more neutral or alkaline the pH, the longer ALS-inhibiting herbicides may persist in the soil.

A common practice for Oklahoma wheat producers is to apply a residual ALS-inhibiting herbicide in late winter to obtain weed control through harvest. Most winter canola cultivars are reportedly very sensitive to sulfonylurea herbicide residues (Anonymous, 2009b). Herbicide labels often restrict seeding canola for several months after the product was applied to wheat. These plant back restrictions often prevent new producers from planting winter canola following winter wheat.

Since most ALS-inhibiting herbicides were registered before winter canola became a crop in Oklahoma, herbicide label restrictions for canola were typically written for spring canola which is grown in the northern part of the United States and southern Canada. In contrast to the situation in Canada, the climate in Oklahoma is more favorable for herbicide degradation during a greater portion of each year, thus existing herbicide label recropping intervals may be too long for the southern Great Plains.

The objective of this research was to determine the response of winter canola to selected ALS-inhibiting herbicides applied to winter wheat during the crop year preceding the planting of winter canola.

MATERIALS AND METHODS

Canola tolerance to selected ALS enzyme inhibiting herbicides (2005-2007). Field experiments were conducted from 2005 to 2007 at Oklahoma State University's Cimarron Valley, (CV), North Central, (NC), and South Central, (SC), Research Stations to evaluate the residual phytotoxity to winter canola of ten ALS-inhibiting herbicides applied to the preceding wheat. In the fall 2005, hard red winter wheat '2174' was seeded at CV and SC, and 'Jagger' at NC in conventionally tilled seedbeds (Table 1).

Herbicide treatments were applied at 1x and 2x of rates registered for use on wheat (Anonymous: 2001, 2002, 2005, 2006a, 2006b, 2006c, 2006d, 2008, 2009a, 2009c) in December 2005.

Soils at the sites were a Teller loam (fine loamy, mixed, thermic Udic Argiustolls) with pH 5.7 and 1.0% organic matter at CV, a Grant silt loam (fine, silty, mixed thermic Udic Argiustolls) with pH 6.0 and 1.8% organic matter at NC, and a Dale silt loam (fine, silty, mixed, superactive, thermic Pachic Haplustolls) with pH 6.5 and 1.1% organic matter at SC. Each experiment was fertilized as required to meet soil test recommendations for 4030 kg/ha wheat yield.

The experimental design for each location was a randomized complete block with a factorial arrangement of treatments. All treatments were replicated four times and plot size was 2.4 by 7.6m. The factors were herbicide treatment applied to wheat in December 2005 and canola cultivar seeded the following fall. The two cultivars were Sumner, a conventional released in 2003 by Kansas State University, noted for its sulfonylurea herbicide tolerance (Boyles et.al, 2004) and DKW 13-86, a glyphosate tolerant cultivar considered sensitive to sulfonylurea herbicide carryover (Anonymous, 2009b).

Herbicide treatments (Table 3) were broadcast with water carrier in a volume of 56 L/ha using a CO_2 pressurized backpack sprayer and a 4 nozzle hand held boom on December 12 or 13, 2005. All treatments included 0.5% v/v of a nonionic surfactant. Winter wheat injury in the form of stunting and chlorosis was visually estimated at CV and NC in March 2006.

Wheat was harvested in late May and early June of 2006 with a small conventional grain combine equipped with a straw chopper. The combine was operated approximately 1.6 km/h to insure that all wheat straw and crop residue was spread evenly across the plot from which it came. Harvested samples were weighed and volume weight and grain moisture content were determined using standard procedures. The data were subjected to analysis of variance. Means were separated using Fishers Protected LSD Test (P = 0.05). Visual estimates of crop injury were arcsine square root transformed before analysis. Original data are shown with means separation from transformed data.

Plots at each location were tilled in June 2006 with a seven shank chisel, with spike tip points, operated at 4.8 km/h 10 to 15 cm deep. The slow speed of the tractor minimized soil movement between plots. In late July and early August, 2006 plots at each location were tilled 8 to 10 cm deep twice with a 1.5 m wide offset disk at 4.8 km/h. At SC glyphosate was broadcast at 2.3 kg ai/ha with 0.5% v/v nonionic surfactant on August 24. Glyphosate was broadcast again at 2.8 kg ai/ha on September 11, to eliminate weeds in plots and plot borders. Due to dry soil conditions that restricted weed growth and glyphosate activity, paraquat dichloride was applied at1.3 kg ai/ha with 0.5% v/v nonionic surfactant on August 10 at CV. This treatment was followed on August 31 by glyphosate at 1.1 kg ai/ha with 0.5 % v/v nonionic surfactant and 20 g/L of ammonium sulfate.

Pre-plant fertilizer was applied in September 2006 according to soil test recommendations to meet the requirements for a canola yield of 3360 kg/ha before final seedbed preparation. An S-tine vibratory field cultivator with double rolling baskets was then operated at 4.8 km/h, 8 to 10 cm deep, twice, to incorporate fertilizer. A 1.5 m wide rolling packer was then used to firm the plots for canola seeding. Winter canola cultivars (DeKalb 13-86 and Sumner) were seeded 1.3 cm deep in appropriate plots with a small plot double-disk opener drill, in rows 17.5 cm apart at 5.6 kg/ha. The canola was seeded on September 24, 2006, ± 3 days. Soil moisture at planting at NC was inadequate for germination.

The experiments were observed at intervals during the fall and winter and when a response to herbicide residues was evident, crop injury was recorded. Thus, response of the winter canola to the residual herbicide was visually estimated at SC on October 24. Observations included emergence, stunting, and effects on leaf color. At CV canola injury was visually estimated on October 5. Visual response data were subjected to arcsine square root transformation prior to analysis. Original data are presented with means separation conducted on transformed data. Stand uniformity was visually estimated on a scale of 0 = no plants present to 100 = uniformly spaced plants of equal size in all rows.

Quizalofop, a herbicide registered for control of weedy grasses in winter canola, was broadcast at 56g/ha with 1% v/v crop oil concentrate for volunteer wheat control on December 14. Lambda-cyhalothrin insecticide was applied at 35 g/ha at NC and CV on March 28 and April 23 for aphid control. The insecticide was applied using a tractor mounted sprayer in 76 L/ha total spray volume with water carrier.

To determine the effect of the herbicide residues on canola yield, each plot was harvested with a small plot combine on June 9, 2006 ± 3 days. The harvested samples from SC were weighed and then placed in a drying facility for a week prior to cleaning due to their high moisture at harvest. Samples were reweighed after drying. The seed was cleaned with a small commercial seed cleaner to remove unwanted canola plant material. Seed from each plot was reweighed and volume weight and seed moisture content were determined using standard procedures. Seed moisture at harvest of samples from SC was determined by adding moisture lost by drying to the moisture content of dried seed. Yields were corrected to 10% moisture. All data were subjected to analysis of variance. Means were separated using Fishers Protected Least Significant Difference Test (P = 0.05).

Canola tolerance to selected ALS enzyme inhibiting herbicides (2006-2008). The field experiments were repeated beginning in the fall 2006 at sites adjacent to the previous sites on the same soils. The site at NC was abandoned due to stand failure of the canola. The pH was 6.3 and 6.4 at CV and SC and organic matter contents were 1.2 and 1.5 at these respective sites. Winter wheat cultivars were, Jagger at CV, Overly at NC, and OK Bullet at SC. The same herbicide treatments were applied to the winter wheat in December 2006.

Other procedures were conducted as previously described except that the herbicide treatment carrier volume was increased to 87 L/ha and there were minor variations in summer tillage and summer weed control procedures. Also, canola was seeded on October 4 ± 1 day, and the quizalofop was applied at 70 g/ha on November 4 ± 3 days for volunteer wheat control. In addition the insecticide was applied in November and March for aphid control. Canola plots were evaluated for response to herbicide treatment in November and March.

Canola tolerance to multiple rates of chlorsulfuron + metsulfuron (2006-2007). Field experiments were conducted at CV, NC, and SC to evaluate the response of canola to a wide range of rates of chlorsulfuron + metsulfuron applied to winter wheat in February 2006 preceding planting winter canola in the fall of 2006. All experiments were established in fields of wheat planted by research station personnel. Pioneer 2174 winter wheat was seeded at SC and CV, and Overly was seeded at NC (Table 2). Soils varied from earlier experiments only in pH and organic matter content. Soil pH was 5.4, 5.8, and 6.7 at CV, NC, and SC, respectively. Organic matter contents were 1.2% at CV and SC and 1.8% at NC. The sites were fertilized to meet the soil test recommendations for yield goals of 4030 kg/ha of wheat and 3360 kg/ha of canola

The experimental design for each location was a randomized complete block with a factorial arrangement of treatments, and four replications. Plot size was 2.6 by 7.6m at SC and CV, and 3 by 7.6 at NC. The factors were herbicide rate and winter canola cultivar (Sumner and DeKalb DKW 13-86).

Chlorsulfuron + metsulfuron (5:1 ratio premix of a commercial formulation) rates were zero, one-half, one, two, three, four, and five times the typical application rate registered for use on winter wheat (Anonymous, 2001). Herbicide treatments were applied to winter wheat at CV on February 14 and at NC and SC on February 15, 2006. Herbicide treatments were broadcast as previously described except that carrier volume was 76 L/ha. All treatments included 0.5% v/v nonionic surfactant. Wheat was harvested in late May and early June of 2006 with a small plot combine. Samples were weighed and volume weight and seed moisture content were determined using standard procedures. All data were subjected to analysis of variance. Means were separated using Fishers Protected Least Significant Difference Test (P = 0.05). Yield, volume weight and grain moisture data were also subjected to regression analysis.

Following wheat harvest, plots were tilled as previously described. The same herbicide treatments were applied at CV and SC as previously described for the 2005-2007 experiments.

Prior to canola seeding, fertilizer was applied accordingly to soil test recommendations for canola yield of 3360 kg/ha. One third of the required nitrogen was applied in the fall and the balance in February. Pre-plant fertilizer included 240 kg/ha of 18-46-0 at SC, 112 kg/ha of 18-46-0 at NC, and 170 kg/ha of 19-19-19 at CV. An S-tine field cultivator with double rolling baskets was operated 10 to14 cm deep at 4.8 km/h to incorporate fertilizer. Tractor speed was reduced to this slower speed to minimize soil movement between plots. The field cultivator was operated in one direction and then in the opposite direction down each plot to further minimize soil movement between plots. Plots were firmed with a 1.5 m wide packer immediately before planting.

Winter canola cultivars (Sumner and DeKalb 13-86) were seeded 1 to 2 cm deep in appropriate plots in rows 17.5 cm wide on September 24 ± 3days. Seeding rate was 5.6 kg/ha. Other procedures were as described for the experiment initiated in 2005.

RESULTS AND DISCUSSION

Canola tolerance to selected ALS-enzyme inhibiting herbicides (2005-2007) and (2006-2008). Chlorsulfuron + flucarbazone, propoxycarbazone, and sulfosulfuron at its high rate caused visible chlorosis and or slight wheat stunting at CV and NC (Table 3). Stunting was most obvious in plots treated with the higher rate of propoxycarbazone. The lower rate of chlorsulfuron + flucarbazone and propoxycarbazone are typical rates used on wheat, but they still caused some chlorosis. The labels for these herbicides caution that crop injury may occur when the herbicides are applied when wheat is stressed by frost, subjected to extreme temperatures such as cold weather, and or when extreme moisture conditions occur. The chlorosis was attributed to reoccurring cold temperatures and temperature fluctuations following application of these herbicides in December.

No herbicide treatments affected yield of wheat harvested at CV in June 2006 (P = 0.66). Pooled across NC and SC compared to the untreated, only chlorsulfuron at the higher rate reduced wheat yield (Table 3). Wheat yield in plots treated with the low rate of chlorsulfuron + metsulfuron yielded more (P = 0.018) than plots treated with thirteen other herbicide treatments. Also, wheat yields from plots treated with sulfosulfuron and thifensulfuron + tribenuron at their higher rates were higher than yields of ten and four other herbicide treatments, respectively. Thus, the slight chlorosis and stunting observed on wheat with sulfosulfuron at the higher rate did not affect grain yield. This was also true with propoxycarbazone and chlorsulfuron + flucarbazone. Since weeds were sparse at both locations, crop response to the herbicides would seem responsible for the yield differences. The literature does indicate that higher rates of chlorsulfuron can reduce wheat yields (Brewster and Appleby, 1983; Ferreira et al, 1990). Thus, crop injury cannot be ruled out as potential cause of the lower wheat yields observed in plots treated with the high rate of chlorsulfuron.

In June 2007, winter wheat yields at NC and SC were not affected by herbicide treatment (P = 0.32, 0.88). Mean wheat yields were (1757 kg/ha) and (2790 kg/ha) at NC and SC. Wheat at CV was not harvested due to late a spring freeze that destroyed the crop.

Visual estimates of canola phytotoxity at CV in the fall of 2006 indicated that neither herbicide treatment ($P = 0.09$), nor cultivar ($P = 0.28$) was the source of minor variations in canola vigor. Also no interaction was found between herbicide treatment and cultivar ($P = 0.36$). Mean phytotoxity was only 3.6%. At SC, cultivar did affect stand uniformity ($P = 0.0001$) with DKW 13-86 evaluated as 73% uniform and Sumner 65%. Stand uniformity may have been related to differences in vigor of the seed of the two cultivars. Herbicide treatment did not affect stand uniformity ($P = 0.34$).

There was a strong interaction ($P = 0.001$) between cultivar and herbicide treatment in the visual estimates of leaf deformity in the fall of 2006 at SC (Table 4). No herbicide treatment affected Sumner. Among the herbicide treatments, those with Sulfosulfuron caused the most leaf deformity of DKW 13-86 at 95% followed by treatments containing propoxycarbazone (Table 4). The interval specified on the product labels for sulfosulfuron application and planting a canola cultivar that contains no tolerance to sulfonylurea herbicides is 22 months plus cumulative precipitation of 76cm. For canola cultivars that exhibit tolerance to sulfonylurea herbicides the interval is 3 months plus 46 cm of cumulative precipitation. The interval is 22 months for propoxycarbazone plus 60 cm of cumulative precipitation (Anonymous: 2006d, 2009c). These are the longest rotational intervals on labels of the herbicides investigated.

Visual estimates for canola stunting in October 2006 also indicated a strong interaction between cultivar and herbicide treatments ($P = 0.0001$) (Table 4). In addition to the treatments that caused deformed leaves, mesosulfuron, propoxycarbazone + mesosulfuron, and triasulfuron, each at their 2x rate, significantly stunted DKW 13-86 but not the herbicide tolerant cultivar Sumner. In November 2006 canola stunt data indicated a continuing strong interaction between cultivar and herbicide treatment (P = 0.0001) (Table 4).

By November, all plots with Sumner appeared somewhat stunted. This was considered a result of differences in growth habit between the two cultivars rather than herbicide-induced stunting. The data indicates that the DKW 13-86 had not recovered from stunting observed the previous month.

Canola seed yield was not influenced by herbicide treatment at any site either year (Table 5). In 2007 canola seed yield was pooled across CV and NC (P = 0.95). A cultivar influence was found (P = 0.0003) (Table 5). DKW 13-86 yielded more (2920 kg/ha) than Sumner (2730 kg/ha). At SC no interaction between herbicide treatments and cultivars (P = 0.3) was found in the seed yield data. A cultivar influence was found (P = 0.0001). Canola seed yield of DKW 13-86 was 2730 kg/ha and Sumner was 3520 kg/ha. In June 2008, canola seed yields were pooled across CV and SC (P = 0.08). There was no interaction of herbicide treatment and cultivar (P = 0.46). Mean canola yield was 1488 kg/ha. The NC site was abandoned due to dry planting conditions which resulted in a poor stand.

Canola seed moisture content at harvest was not affected by herbicide treatments at any location either year (Table 6). Seed moisture content was influenced by cultivar (P = 0.0001) at all sites, except CV in 2008. Mean seed moisture content for CV in 2008 was 9.85%. Sumner is an earlier maturing cultivar than DKW 13-86, thus Sumner was expected to be drier at harvest (Anonymous, 2009b).

Herbicide treatment did not affect seed volume weight at any location either year. Pooled across herbicide treatment in 2007, volume seed weight of Sumner was slightly higher (P = 0.0001) than DKW 13-86 at NC (Table 7). At SC, cultivar did not affect (P = 0.45) seed volume weight. Mean seed volume weight at SC in 2007 was 68.85 kg/hl. In 2008, volume seed weight of DKW 13-86 at CV was higher (P = 0.0001) and at SC (P = 0.0003) (Table 7).

The dockage in canola was pooled across sites CV and NC and herbicide treatments in 2007 (P = 0.41). At these sites the 6.0% dockage in DKW 13-86 was less than (P = 0.0004) the 7.3 % dockage in Sumner. At SC no interaction was found between herbicide treatment and cultivar (P = 0.34) nor did herbicide treatment affect dockage (P = 0.74). Pooled over other factors the 5.5% dockage in DKW 13-86 was greater (P = 0.04) than the 4.8% dockage in Sumner.

In 2008 canola seed was clean at harvest at SC, thus no attempt was made to re-clean the samples to estimate dockage. Analysis of dockage data from CV revealed no interaction between herbicide treatment and cultivar (P = 0.62). Also, neither herbicide treatment nor cultivar (P = 0.36, 0.13) affected dockage. The mean dockage was 13.0 %. Dockage at all sites consisted primarily of canola stem and pod material collected with harvested seed. When differences between the cultivars were found they were attributed to differences in maturity, stature, and other cultivar specific traits. The lack of detectable herbicide effects indicated that herbicide residues did not affect canola growth or maturity.

These data suggest that product labels may be excessively conservative regarding rotational restrictions to canola. With the possible exception of sulfosufuron and propocarbazone, which caused visual injury at SC where the pH was 6.5, there was no evidence that application of ALS inhibiting herbicides applied to wheat reduced the yield of winter canola planted the following fall.

Canola tolerance to multiple rates of chlorsulfuron + metsulfuron (2006-2007). Pooled across all locations winter wheat yield was not affected by herbicide treatment ($P = 0.46$). Mean wheat yield was (2332 kg/ha). Regression analysis of yields of Sumner verses herbicide rate at CV, NC, and SC provided r^2 values of 0.095, 0.349, and 0.020, respectively, indicating very weak relationships between Sumner canola yield and rates of herbicide applied the previous year. These results were not unexpected because Sumner is considered tolerant to the herbicide. However, regression analysis of yields of DKW 13-86 at these same locations produced r^2 values of 0.442, 0.024, and 0.022. These results clearly demonstrated poor relationships between yield of DKW 13-86 and rate of herbicide applied the previous year. Herbicide treatments applied at all locations in February 2006 did not have an effect on DKW 13-86 or Sumner yield.

Degradation of these herbicides is dependent on soil pH, with more rapid acid hydrolysis occurring at lower pH, soil moisture content, soil temperature, and soil microorganisms (Anonymous, 2001). The label for the product used specifies rotational intervals for three broadleaf crops in Oklahoma, i.e. cotton, mungbeans, and soybeans. With soil pH less than 7.9 the rotational interval for these crops is 14 months plus 64 cm of cumulative precipitation. In these studies, cumulative precipitation was 38 to 53 cm and the rotational interval less than seven months. The data suggest that winter canola can safely be grown with a much shorter rotational interval than recommended for other broadleaf crops on the product label.

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Table 1. Dates of field activities and rainfall received for the canola tolerance to selected herbicides experiments conducted from 2005-2007 at three locations and from 2006-2008 at two locations.

	2005-2007			2006-2008	
Field activity and rainfall	CV[a]	NC	SC	CV	SC
Wheat seeded	10/7/05	10/15/05	9/24/05	9/20/06	9/22/06
Herbicide applied	12/12/05	12/12/05	12/13/05	12/12/06	12/12/06
First rainfall (DAT)	28	5	4	7	7
First rainfall (cm)	0.4	0.9	0.3	1.3	2.1
Total rainfall 30 DAT	0.8 cm	1.2 cm	0.8 cm	5.7 cm	5.7 cm
Wheat harvested	5/24/06	6/6/06	6/5/06	7/10/07	6/7/07
Chisel plow tillage	6/14/06	6/13/06	6/29/06	8/29/07	8/29/07
Disc tillage	7/24/06	7/6/06	8/3/06	10/207	10/2/07
Canola seeding date	9/22/06	9/21/06	9/27/06	10/3/07	10/5/07
Canola seeding (MAT)	9.5	9.5	9.6	9.8	9.8
Total rainfall (cm)[b]	49	40	55	123	116
Canola harvested	6/6/07	6/12/07	6/7/07	6/5/08	6/3/08

[a]Abbrevations: CV, Cimarron Valley Research Station; NC, North Central Research Station; SC, South Central Research Station; DAT, days after treatment; MAT, months after treatment.
[b]Total rainfall from herbicide application to canola seeding.

Table 2. Dates of field activities and rainfall received for the canola tolerance to multiple rate to chlorsulfuron + metsulfuron experiments conducted from 2006-2007 at three sites.

Field activity and rainfall	CV[a]	NC	SC
Wheat seeded	10/7/05	10/15/05	9/24/05
Herbicide applied	02/14/06	02/15/06	02/15/06
First rainfall (DAT)	8	19	6
First rainfall (cm)	0.4	0.23	0.76
Total rainfall 30 DAT (cm)	0.8	2.1	1.1
Wheat harvested	5/31/06	6/1/06	6/1/06
Chisel plow tillage	6/14/06	6/13/06	6/29/06
Disc tillage	7/24/06	7/6/06	8/3/06
Canola seeding date	9/22/06	9/21/06	9/27/06
Canola seeding (MAT)	6.2	6.2	6.4
Total rainfall (cm)[b]	47	38	53
Canola harvested	6/18/07	6/12/07	6/7/07

[a] Abbreviations: CV, Cimarron Valley Research Station; NC, North Central Research Station; SC, South Central Research Station; DAT, days after treatment; MAT, months after treatment.

[b]Total rainfall from herbicide application to canola seeding.

*Table 3.*Visual estimates of wheat injury in March 2006 from herbicide treatments applied in December 2005 at two sites and wheat yields in June 2006 at three sites.

Herbicide	Rate	Chlorosis		Stunting		Yield	
		CV	NC	CV	NC	CV	Mean[b]
	g ai/ha	%				kg/ha	
Chlorsulfuron	13.1	1.0	0	0.3	0	1590	2880
Chlorsulfuron	26.2	2.4	0	0.6	0	1640	2570
Chlor + flu.	13.1+24.6	9.4	3.1	9.4	0.6	1680	2840
Chlor. + flu.	26.2+49.1	11.6	1.9	11.6	0.6	1650	2830
Chlor. + met.	13.1+2.6	3.1	0	1.3	0	1730	3170
Chlor + met.	26.2+5.2	4.1	0	1.9	0	1510	2900
Mesosulfuron	15.0	0.6	0	0.6	0	1600	2810
Mesosulfuron	29.9	0.9	0	0.6	0	1610	2810
Metsulfuron	4.2	0.6	0	0	0	1590	2810
Metsulfuron	8.4	2.1	0	0.6	0	1650	2940
Prop.	44.2	7.3	7.3	3.6	1.5	1540	2920
Prop.	88.6	11.9	10.6	5.6	7.5	1560	2800
Prop. + Mes.	14.1 + 9.4	3.1	0.6	1.9	0.6	1490	2710
Prop. + Mes.	28.3 + 18.8	5.3	2.5	3.1	0	1510	2930
Sulfosulfuron	34.8	0.6	0	0.6	0	1490	2830
Sulfosulfuron	69.9	6.9	0	4.3	0	1640	3120
Thif.+ trib.	15.7 + 7.9	3.1	0	1.3	0	1530	2950
Thif.+ trib.	31.4 + 15.8	0.6	0	0.6	0	1520	3090
Triasulfuron	18.4	0	0	0	0.1	1640	2800
Triasulfuron	36.8	0	0	0	0	1550	2740
untreated	0	0.4	0	0.3	0	1580	2860
LSD (P = 0.05)		5.8	1.6	3.5	2.3	NSD	282

[a]Abbreviations: SC, South Central Research Station; chlor. + flu., chlorsulfuron plus flucarbazone; chlor. + met, chlorsulfuron plus metsulfuron; prop., propoxycarbazone; prop. + mes., propoxycarbazone plus mesosulfuron; thif. + trib, thifensulfuron + tribenuron.

[b]Mean indicates data pooled across NC and SC.

Table 4. Response of canola seeded in September 2006 to herbicide treatments applied in December 2005 at SC[ab].

				Stunting			
		Deformed leaves		October 2006		November 2006	
Herbicide	Rate	DKW13-86	Sumner	DKW13-86	Sumner	DKW13-86	Sumner
	g ai/ha	%					
Chlorsulfuron	13.1	1 ef	0 e	3 de	2 e	15 c-h	25 cd
Chlorsulfuron	26.2	3 ef	0 e	2 de	1 e	13 c-h	13 c-h
Chlor + flu.	13.1+24.6	1 ef	0 e	1 e	0 e	5 e-h	18 c-e
Chlor. + flu.	26.2+49.1	1 ef	0 e	2 de	0 e	5 gh	13 c-h
Chlor. + met.	13.1+2.6	2 ef	0 e	1 e	1 e	3 h	15 c-f
Chlor + met.	26.2+5.2	1 ef	0 e	2 de	0 e	8 f-h	20 c-f
Mesosulfuron	15.0	4 e	0 e	2 de	1 e	16 c-f	18 c-g
Mesosulfuron	29.9	0 e	0 ef	21 c	1 e	20 cd	20 cd
Metsulfuron	4.2	0 e	0 e	2 de	0 e	19 c-g	18 c-e
Metsulfuron	8.4	0 e	1 ef	4 cde	1 e	23 cd	20 c-f
Prop.	44.2	58 c	0 e	54 b	1 e	55 ab	30 bc
Prop.	88.6	65 c	0 e	48 b	0 e	56 ab	18 c-g

Prop. + Mes.	14.1 + 9.4	3 e	0 e	0 e	1 e	14 c-h	16 c-f
Prop. + Mes.	28.3 + 18.8	15 d	0 ef	15 c	1 e	31 bc	23 cd
Sulfosulfuron	34.8	85 b	0 e	81 a	1 e	54 ab	14 c-g
Sulfosulfuron	69.9	95 a	0 e	61 b	1 e	69 a	20 cd
Thif.+ trib.	15.7 + 7.9	0 e	0 e	1 e	1 e	15 c-h	13 c-h
Thif.+ trib.	31.4 + 15.8	2 ef	2 ef	2 de	1 e	15 c-h	18 c-e
Triasulfuron	18.4	1 ef	0 e	1 e	1 e	10 d-h	25 cd
Triasulfuron	36.8	1 ef	0 e	13 cd	0 e	28 cd	13 c-g
untreated	0	0 e	0 e	0 e	0 e	5 e-h	13 c-h

[a]Abbreviations: SC., South Central Research Station; chlor. + flu., chlorosulfuron plus flucarbazone; chlor. + met., chlorosulfuron plus metsulfuron; prop., propoxycarbazone; prop. + mes., propoxycarbazone plus mesosulfuron; thif. + trib., thifensulfuron + tribenuron.
[b] % Means within each observation followed by the same letter are not significantly different (P = 0.05).

Table 5. Effect of cultivar pooled across herbicide treatments on yield of winter canola harvested from canola tolerance to selected residual herbicide experiments at three sites in June 2007 and at two sites in June 2008.

	2007		2008
Cultivar	Mean[a]	SC[b]	Mean[c]
DKW 13-86	2920	2730	1260
Sumner	2730	3520	1710
LSD (0.05)	100	120	NSD
P value	0.0003	0.0001	0.45
CV (%)	16	13	382

[a]Pooled across experiments at the Cimarron Valley; and North Central Research Station (P=0.95).
[b]Abbreviation: SC, South Central Research Station.
[c]Pooled across experiments at the South Central; and Cimarron Valley Research Station (P=0.46).

Table 6. Effect of cultivar pooled over herbicide treatments on seed moisture content (%) of winter canola harvested from canola tolerance to selected residual herbicide experiments at three sites in June 2007 and at two sites in June 2008.

	2007			2008	
Cultivar	CV[a]	NC	SC	CV	SC
DKW 13-86	13.4	12.5	21.9	9.8	7.8
Sumner	11.7	11.5	17.8	9.9	6.4
LSD (0.05)	0.3	0.4	1.4	NSD	0.3
P-value	0.0001	0.0001	0.0001	0.6	0.0001
CV (%)	8.7	12	8.2	14	14.4

[a]Abbreviations: CV, Cimarron Valley Research Station; NC, North Central Research Station; SC, South Central Research Station.

Table 7. Effect of cultivar pooled across herbicide treatments on volume seed weight (kg/hl) of winter canola harvested in the canola tolerance to selected residual herbicide experiments at two sites in June 2007 and 2008.

	2007		2008	
Cultivar	NC[a]	SC	CV	SC
DKW 13-86	65.2	66.8	56.8	63.0
Sumner	65.8	66.9	53.4	62.3
LSD (0.05)	0.2	NSD	1.4	0.5
P-value	0.0001	0.45	0.0001	0.0003
CV (%)	1.4	1.6	8.6	2.7

[a]Abbreviations: CV, Cimarron Valley Research Station; NC, North Central Research Station; SC, South Central Research Station.

Appendix A. Common name, major degradation pathway, half-life and time required (rotation interval) between herbicide application and planting canola specified of the product label for each herbicide for its residual effects on canola.[a]

Common name	Degradation	Half-life	Rotational interval
		d	
Chlorsulfuron	Hydrolysis	28-42	Field Bioassay[b]
Chlorsulfuron+flucarbazone-sodium	Microbial	28-42+17	Field Bioassay
Chlorsulfuron+metsulfuron-methyl	Hydrolysis	---	Field Bioassay
Mesosulfuron-methyl	Microbial	---	10 months
Metsulfuron-methyl	Microbial	7-30	10 months
Propoxycarbazone-sodium	Microbial	9	22 months
Propoxycarbazone-sodium+Mes.[c]	Microbial	---	12 months
Sulfosulfuron	Hydrolysis	14-75	22 months
Thifensulfuron-methyl + trib.	Hydrolysis	10	60 days
Triasulfuron	Hydrolysis	11-95	Field Bioassay

[a]Sources: Herbicide Handbook (9th ed.) 2007. Weed Science Society of America, Lawrence, KS. Osprey Herbicide Technical Bulletin 2003. Bayer CropScience. Research Triangle Park, NC.
[b]Field Bioassay is defined on the label as growing test strips of the crop or crops you plan to grow in the following year in fields previously treated. Crop response will indicate whether or not to rotate to crops that are being grown in the test strips. Thus, field bioassay suggests a minimum herbicide application to rotational crop seeding interval of 12 months.
[c]Abbreviations: Mes., Mesosulfuron-methyl, trib., tribenuron-methyl.

Appendix B. Effect of cultivar and herbicide treatment applied to the preceding wheat crop in December 2005 on the seed volume weight, moisture content and yield of canola seeded in the fall of 2006.

			VW[a]		Moisture			Yield		
Cultivar	Herbicide	Rate	SC[b]	NC	SC	NC	CV	SC	NC	CV
		g ai/ha	— kg/hl —		——— % ———			——— kg/ha ———		
DKW 13-86	Chlorsulfuron	13.1	67.5	65.3	19.2	11.8	13.5	2890	2320	3410
	Chlorsulfuron	26.2	67.1	64.4	22.1	14.0	14.2	2960	2610	3540
	Chlor. + flu.	13.1+24.6	66.3	65.2	24.3	13.1	13.3	2630	2790	3350
	Chlor. + flu.	26.2+49.1	66.4	65.6	23.4	11.4	13.8	2700	2490	3730
	Chlor. + met.	13.1+2.6	66.0	65.3	25.4	11.5	14.1	2790	2110	3300
	Chlor. + met.	26.2+5.2	65.8	65.0	22.6	12.2	13.6	2910	2520	3050
	Mesosulfuron	15.0	67.3	64.3	18.0	14.8	14.2	3330	2350	3560
	Mesosulfuron	29.9	67.6	65.0	19.1	13.5	13.8	2730	2330	3580
	Metsulfuron	4.2	65.7	65.0	21.4	12.8	14.1	2730	2860	3690
	Metsulfuron	8.4	67.1	65.2	20.3	11.8	12.2	3010	2320	3170
	Prop.	44.2	66.9	65.2	23.4	13.2	12.5	2340	2660	3470
	Prop.	88.6	67.2	65.5	18.5	13.0	13.7	2600	2230	3280
	Prop. + mes.	14.1+9.4	67.2	65.2	24.1	12.8	13.2	2490	2620	3490
	Prop. + mes.	28.3+18.8	66.8	65.0	23.5	12.9	12.5	2620	2540	3490
	Sulfosulfuron	34.8	65.3	64.7	27.9	12.4	12.9	2430	2240	3580
	Sulfosulfuron	69.9	67.7	65.0	20.8	11.8	14.2	2360	2540	3440
	Thif. + trib.	15.7+7.9	66.6	65.3	21.9	11.7	13.3	2930	2040	3610
	Thif. + trib.	31.4+15.8	65.9	66.1	17.2	11.1	12.9	2730	1740	3560
	Triasulfuron	18.4	66.3	65.1	21.5	11.8	13.3	2650	2100	3520
	Triasulfuron	36.8	66.8	65.0	22.8	12.7	13.6	3080	2560	3460
	Untreated	---	66.9	65.8	22.6	10.9	13.7	2470	1990	3540
Sumner	Chlorsulfuron	13.1	66.6	65.1	18.9	11.8	11.3	3520	2080	3480
	Chlorsulfuron	26.2	67.5	65.9	16.2	11.3	12.3	4040	2180	3230
	Chlor. + flu.	13.1+24.6	66.8	66.1	18.5	11.2	12.5	3320	2530	3380
	Chlor. + flu.	26.2+49.1	67.0	66.5	18.5	11.2	11.9	3550	2270	3570
	Chlor. + met.	13.1+2.6	66.6	66.2	17.4	11.2	11.7	3180	2000	3160
	Chlor. + met.	26.2+5.2	67.1	65.8	16.8	11.1	12.1	3440	2440	3210
	Mesosulfuron	15.0	67.2	65.7	18.4	11.4	10.7	3390	2350	3290
	Mesosulfuron	29.9	66.5	64.4	18.3	13.1	12.0	3670	2130	3370
	Metsulfuron	4.2	66.9	66.1	18.8	11.8	12.2	3240	1900	3320
	Metsulfuron	8.4	67.0	66.0	17.3	11.0	11.2	3560	1940	3390
	Prop.	44.2	66.6	65.5	17.5	11.4	11.1	3570	2040	3500

Prop.	88.6	66.9	65.5	15.3	11.6	11.3	3670	2420	3210
Prop. + mes.	14.1+9.4	66.5	66.8	17.4	10.7	11.8	3260	2100	3430
Prop. + mes.	28.3+18.8	67.0	66.1	19.0	10.8	11.5	3460	2200	3470
Sulfosulfuron	34.8	66.6	66.4	18.3	10.9	12.1	3750	1590	3390
Sulfosulfuron	69.9	67.0	65.8	17.0	12.3	13.0	3520	2120	3230
Thif.+trib.	15.7+7.9	66.9	66.1	17.8	11.8	13.3	3530	1950	3320
Thif.+trib.	31.4+15.8	65.6	65.8	18.7	11.3	11.8	3430	1980	3280
Triasulfuron	18.4	66.2	64.7	18.4	13.2	11.1	3780	2380	3290
Triasulfuron	36.8	66.9	65.6	17.6	11.3	11.6	3720	2010	3310
Untreated	---	67.5	65.6	17.9	11.1	11.7	3290	1840	3430
LSD (0.05)		NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD
CV (%)		8.2	1.4	1.8	12	8.7	13	27.2	8.3

[a]Abbreviations: VW, volume weight; SC, South Central Research Station; NC, North Central Research; CV, Cimarron Valley Research Station; chlor. + flu., chlorsulfuron plus flucarbazone; chlor. + met., chlorsulfuron plus metsulfuron; prop., propoxycarbazone; prop. + mes., propoxycarbazone plus mesosulfuron; thif. + trib., thifensulfuron + tribenuron.

Appendix C. Effect of cultivar and herbicide treatment applied to the preceding wheat crop in December 2006 on the seed volume weight, moisture content and yield of canola seeded in the fall 2007.

			VW[a]		Moisture		Yield	
Cultivar	Herbicide	Rate	SC	CV	SC	CV	SC	CV
		g ai/ha	—— kg/hl ——		—— % ——		—— kg/ha ——	
DKW 13-86	Chlorsulfuron	13.1	64.1	55.8	8.4	10.8	2690	980
	Chlorsulfuron	26.2	62.7	57.4	8.0	10.3	2990	1010
	Chlor. + flu.	13.1+24.6	63.1	56.2	7.6	10.9	3120	980
	Chlor. + flu.	26.2+49.1	62.7	58.1	7.80	10.1	2830	1110
	Chlor. + met.	13.1+2.6	63.2	57.1	7.4	10.5	2900	1080
	Chlor. + met.	26.2+5.2	63.3	56.1	7.5	10.0	2930	1040
	Mesosulfuron	15.0	63.4	58.5	8.5	9.6	2860	1000
	Mesosulfuron	29.9	63.7	58.0	8.1	10.7	3010	940
	Metsulfuron	4.2	63.1	56.4	7.7	9.3	2960	890
	Metsulfuron	8.4	63.5	57.0	7.6	10.9	2490	820
	Prop.	44.2	63.8	55.5	7.6	9.7	2630	870
	Prop.	88.6	63.5	56.8	8.0	8.3	2700	1000
	Prop. + mes.	14.1+9.4	62.6	58.7	7.6	10.0	2840	1090
	Prop. + mes.	28.3+18.8	62.9	60.1	8.5	9.7	2730	1170
	Sulfosulfuron	34.8	63.1	57.9	7.5	10.3	2560	960
	Sulfosulfuron	69.9	63.3	56.8	7.3	9.6	2650	930
	Thif. +trib.	15.7+7.9	62.0	59.4	8.7	8.5	2910	990
	Thif. +trib.	31.4+15.8	61.3	58.8	8.3	8.9	2610	940
	Triasulfuron	18.4	61.9	57.4	7.7	9.3	2950	1020
	Triasulfuron	36.8	62.9	44.7	7.5	10.2	2470	970
	Untreated	---	64.3	56.1	7.5	10.1	3030	920
Sumner	Chlorsulfuron	13.1	62.6	53.2	6.3	10.7	2320	1020
	Chlorsulfuron	26.2	62.7	52.2	6.6	10.4	2400	870
	Chlor. + flu.	13.1+24.6	62.6	55.0	6.3	9.3	2520	950
	Chlor. + flu.	26.2+49.1	62.0	54.3	6.5	9.6	2690	1080
	Chlor. + met.	13.1+2.6	64.1	55.8	6.5	9.3	2880	920
	Chlor. + met.	26.2+5.2	62.5	52.9	6.4	10.4	2490	980
	Mesosulfuron	15.0	63.0	56.6	6.3	9.9	2590	970

Mesosulfuron	29.9	62.5	54.2	6.2	9.4	2340	960
Metsulfuron	4.2	61.7	51.6	6.3	9.4	2350	820
Metsulfuron	8.4	63.0	54.4	6.2	10.0	2400	990
Prop.	44.2	60.9	52.4	6.2	9.7	2310	900
Prop.	88.6	62.9	52.5	6.1	9.4	2270	810
Prop. + mes.	14.1+9.4	62.3	54.1	6.3	10.9	2610	940
Prop. + mes.	28.3+18.8	63.2	54.4	6.4	9.0	2970	1110
Sulfosulfuron	34.8	63.4	52.4	6.1	9.7	2250	970
Sulfosulfuron	69.9	59.9	51.6	6.0	10.7	2600	800
Thif. + trib.	15.7+7.9	61.7	52.0	6.5	11.1	2740	820
Thif. + trib.	31.4+15.8	61.7	52.6	6.7	10.8	2330	850
Triasulfuron	18.4	62.0	53.3	6.3	10.2	2430	990
Triasulfuron	36.8	61.8	54.1	6.4	8.9	2490	1100
Untreated	---	61.2	51.9	7.0	10.2	2760	690
LSD (0.05)		NSD	NSD	NSD	NSD	NSD	NSD
CV %		2.7	8.6	14.4	14.2	15.8	17.0

[a]Abbreviations: VW, volume weight; SC, South Central Research Station; NC, North Central Research; CV, Cimarron Valley Research Station; chlor + flu, chlorsulfuron plus flucarbazone; chlor. + met., chlorsulfuron plus metsulfuron; prop., propoxycarbazone; prop. + mes., propoxycarbazone plus mesosulfuron; thif. + trib., thifensulfuron + tribenuron.

Appendix D. Effect of canola cultivar and herbicide treatment applied to the preceding wheat crop on dockage in canola seed harvested in 2007 or 2008 approximately 18 months after the herbicides were applied[a] .

			2007		2008
Cultivar	Herbicide	Rate	CV and NC	SC	CV
		g ai/ha	%		
DKW 13-86	Chlorsulfuron	13.1	5.4	4.4	13.6
	Chlorsulfuron	26.2	5.3	5.3	10.1
	Chlor. + flu.	13.1+24.6	5.4	6.6	13.3
	Chlor. + flu.	26.2+49.1	6.0	5.0	9.6
	Chlor. + met.	13.1+2.6	7.1	5.1	10.6
	Chlor. + met.	26.2+5.2	5.5	4.6	12.5
	Mesosulfuron	15.0	5.8	5.2	12.4
	Mesosulfuron	29.9	4.7	4.9	20.5
	Metsulfuron	4.2	5.0	5.7	14.9
	Metsulfuron	8.4	5.3	5.1	14.1
	Prop.	44.2	4.6	5.2	14.3
	Prop.	88.6	8.4	4.8	11.7
	Prop. + mes.	14.1+9.4	6.4	5.9	10.2
	Prop. + mes.	28.3+18.8	5.0	4.7	9.0
	Sulfosulfuron	34.8	5.4	5.1	11.4
	Sulfosulfuron	69.9	7.4	6.4	13.1
	Thif. +trib.	15.7+7.9	7.2	5.2	9.7
	Thif. +trib.	31.4+15.8	8.2	10.8	9.9
	Triasulfuron	18.4	5.8	5.7	11.5
	Triasulfuron	36.8	4.2	4.8	10.8
	Untreated	---	7.6	5.4	11.7
Sumner	Chlorsulfuron	13.1	7.0	5.0	12.0
	Chlorsulfuron	26.2	7.3	4.8	13.5
	Chlor. + flu.	13.1+24.6	6.4	6.0	14.2
	Chlor. + flu.	26.2+49.1	8.0	5.5	10.5
	Chlor. + met.	13.1+2.6	7.6	6.1	14.0
	Chlor. + met.	26.2+5.2	6.5	4.7	14.4
	Mesosulfuron	15.0	7.0	4.6	10.3

Mesosulfuron	29.9	7.0	4.1	13.4
Metsulfuron	4.2	8.2	5.4	18.7
Metsulfuron	8.4	7.3	7.3	13.1
Prop.	44.2	5.7	3.7	16.2
Prop.	88.6	5.5	3.7	13.5
Prop. + mes.	14.1+9.4	8.9	4.5	14.2
Prop. + mes.	28.3+18.8	5.8	5.2	10.4
Sulfosulfuron	34.8	9.9	4.4	11.4
Sulfosulfuron	69.9	9.5	5.0	16.6
Thif. + trib.	15.7+7.9	7.7	4.9	16.8
Thif. + trib.	31.4+15.8	6.8	4.1	15.3
Triasulfuron	18.4	6.3	3.0	13.7
Triasulfuron	36.8	7.4	4.4	12.4
Untreated	---	7.8	5.5	15.6
LSD (0.05)		NSD	NSD	NSD

[a]Abbreviations: SC, South Central Research Station; NC, North Central Research; CV, Cimarron Valley Research Station; chlor. + flu., chlorsulfuron plus flucarbazone; chlor. + met., chlorsulfuron plus metsulfuron; prop., propoxycarbazone; prop. + mes., propoxycarbazone plus mesosulfuron; thif. + trib., thifensulfuron + tribenuron.

Appendix E. Effect of cultivar and rate of chlorsulfuron + metsulfuron applied to the preceding wheat crop in February 2006 on the seed volume weight, moisture content and yield of canola seeded in September 2006.

		VW[a]			Moisture			Yield		
Cultivar	Rate	SC[a]	NC[a]	CV[a]	SC	NC	CV	SC	NC	CV
	g ai/ha	kg/hl			%			kg/ha		
DKW 13-86	0+0	65.6	59.4	64.5	8.3	19.5	11.0	2307	558	3617
	5.8 + 1.2	65.3	61.5	64.4	8.8	13.9	11.1	2807	698	3721
	11.7 + 2.3	65.5	62.6	64.0	8.8	14.0	11.3	2655	972	3648
	23.4 + 4.7	63.9	62.7	64.6	10.2	13.4	10.8	2680	833	3508
	35.1 + 7.0	65.3	62.6	64.1	10.1	14.3	11.3	2757	534	3766
	46.7 + 9.4	65.6	63.1	64.3	8.8	12.7	11.5	2585	893	3914
	58.4 + 11.7	64.7	62.1	64.0	10.0	14.6	11.3	2589	741	3814
Sumner	0+0	65.8	60.4	64.5	9.1	16.8	11.2	3176	503	3479
	5.8 + 1.2	66.3	60.7	65.1	8.7	18.3	10.9	3321	559	3223
	11.7 + 2.3	66.1	58.0	64.9	8.8	19.3	11.0	2990	434	3015
	23.4 + 4.7	66.5	61.2	65.1	8.8	17.7	11.0	2702	553	3372
	35.1 +7.0	66.5	58.2	65.0	8.1	21.3	11.0	3135	406	3457
	46.7 + 9.4	66.5	60.3	64.7	8.4	16.7	10.9	2828	738	3405
	58.4 + 11.7	66.3	62.8	65.3	8.3	15.5	11.0	2825	675	3366
LSD (0.05)		NSD	NSD	NSD	NDS	NSD	NSD	NSD	NSD	NSD
CV (%)		1.8	4	1	11	18.8	3.3	21.4	40	13.5

[a]Abbreviations: VW, seed volume weight; CV, Cimarron Valley Research Station; NC, North Central Research Station; SC ,South Central Research Station.

VITA

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Candidate for the Degree of

Master of Science

Thesis: TOLERANCE OF WINTER CANOLA (*Brassica napus*) CULTIVARS TO SELECTED RESIDUAL HERBICIDES

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Scope and Method of Study: Winter canola planting continues to increase in Oklahoma and the Southern Great Plains due to the need for a winter broadleaf crop to rotate with winter wheat in order to expand weed control options. ALS-inhibiting herbicides are commonly used in winter wheat each year in this region. Several of these herbicides have rotational crop restrictions that do not permit seeding winter canola the following year. Field experiments were conducted from 2005 to 2007 and repeated from 2006 to 2008 at three sites to evaluate canola tolerance to ten selected ALS-enzyme inhibiting herbicides. Factors included herbicide treatment applied to wheat and canola cultivar seeded the following fall. The two canola cultivars seeded vary in response to ALS herbicides. The ten herbicides, all registered for use in wheat, were applied at 1x and 2x rates. Additional experiments were conducted to investigate the response of the same two canola cultivars to multiple rates (one-half to five times the labeled rate) of chlorsulfuron + metsulfuron.

Findings and Conclusions: Application of ALS-inhibiting herbicides to wheat seeded in December caused visible stunting and chlorosis to canola seeded the following fall at two sites one year and no sites the other year. However, canola yield was not reduced by any herbicide treatment applied to any experiment either year. The data suggest that winter canola can be grown with a much shorter rotational interval than stated on some product labels.

ADVISER’S APPROVAL: Dr. Thomas F. Peeper